

A 3-D Printed Microfluidic Microgravity Microbial Fuel Cell for Satellite Missions

Completed Technology Project (2012 - 2013)



Project Introduction

This project focused on developing bioelectrochemical test units that could be manufactured principally using additive manufacturing (3D printing) methodologies. These units were specifically being designed for use within unmanned satellite missions that can conduct biological experimentation. The units are microbial fuel cells that were designed as a small-scale, microfluidic microgravity system, with the goal of eventually exploring the effects of microgravity on the bioelectrochemical properties of microbes in space. Preliminary microbial fuel cell units were designed, fabricated and tested, and the results serve to guide ongoing flight experiment hardware concept development.

The initial viability of 3D printed reactors was tested using the selected test organism (*S. oneidensis* MR-1) grown in simple 3D printed cassettes to investigate biocompatibility with the candidate print plastic (ABS). After displaying no significant negative response, growth experiments were conducted on *S. oneidensis* MR-1 to yield a metabolic baseline metric and cell count measures to determine current/cell output from the MFCs. Additionally, methodologies for testing *S. oneidensis* activity within the reactor during autonomous (flight) tests were developed. These included optical sensing of colorimetric assays of the reduction of Fe^{+3} to Fe^{+2} , and voltage and current measurement of exoelectrogenic activity. Test media and reaction electrode configurations (single vs. dual electrodes/chambers) were also studied to increase autonomous testing simplicity and reliability. Additionally, methods for automatically deploying the flight test were investigated, including microbial stasis prior to reanimation, media reconstitution, mixing and filling individual test wells, as well as repeated "feeding" of the wells for extended testing. Alternate test organisms were examined, including an *E. coli* strain that was engineered using synthetic biology techniques to perform extracellular electron transport. Together this resulted in a design that resembled previous small-sat strategies such as PharmaSat, that would be able to provide sufficient test replication and parameterization in a 2-3U configuration.

With respect to the bioelectrochemical reactor development, half-shell bioreactors were designed and fabricated using cylindrical wells with carbon felt as the electrode material. Initial prototypes encountered issues in the form of mechanical failure (cracking) during assembly. Several iterations were required before testing yielded valid data, and included improvements in the 3D printer configuration, reactor shell sizing, fluid containment, membrane sealing and electrode configuration. Ultimately, successful data were obtained for voltage and current generation from four bioelectrochemical wells measured in parallel. Scanning electron microscope imaging was performed and indicated that *S. oneidensis* adhered to the carbon felt electrodes (beneficial). More complex reactor configurations were also printed (PharmaSat configuration) but full-scale testing was not attempted. Further refinement of printing resolution and membrane insertion are required.



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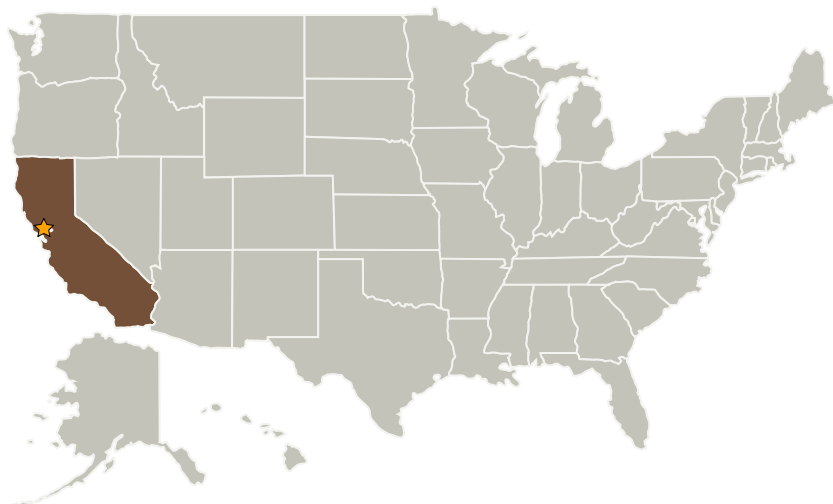


Anticipated Benefits

The reactors developed from this additive manufacturing approach have the potential to be utilized on the International Space Station for performing biological experimentation. The small size of the reactor and autonomous operation would allow a large number of sample wells to be conducted in a minimal volume, thereby increasing the efficiency of experimentation in space.

This novel method of reactor design and fabrication is particularly well-suited for future small-satellite missions due to its minimal size, power and mass. Likewise the project is designed to provide new methods to produce microfluidic, biological test reactors for use in unmanned satellite missions.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★ Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Harry Partridge

Project Manager:

John A Hogan

Principal Investigator:

John A Hogan

Co-Investigators:

John R Cumbers
Antonio J Ricco

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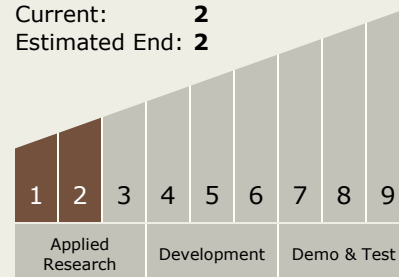
California

Stories

1676 Approval #17536
(<https://techport.nasa.gov/file/8746>)

Technology Maturity (TRL)

Start: **1**
Current: **2**
Estimated End: **2**



Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
 - └ TX11.1 Software Development, Engineering, and Integrity
 - └ TX11.1.2 Verification and Validation of Software systems